Volume 30 July, 1944 *Number 7*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Oil "Breakdown"?

PUBLISHED BY
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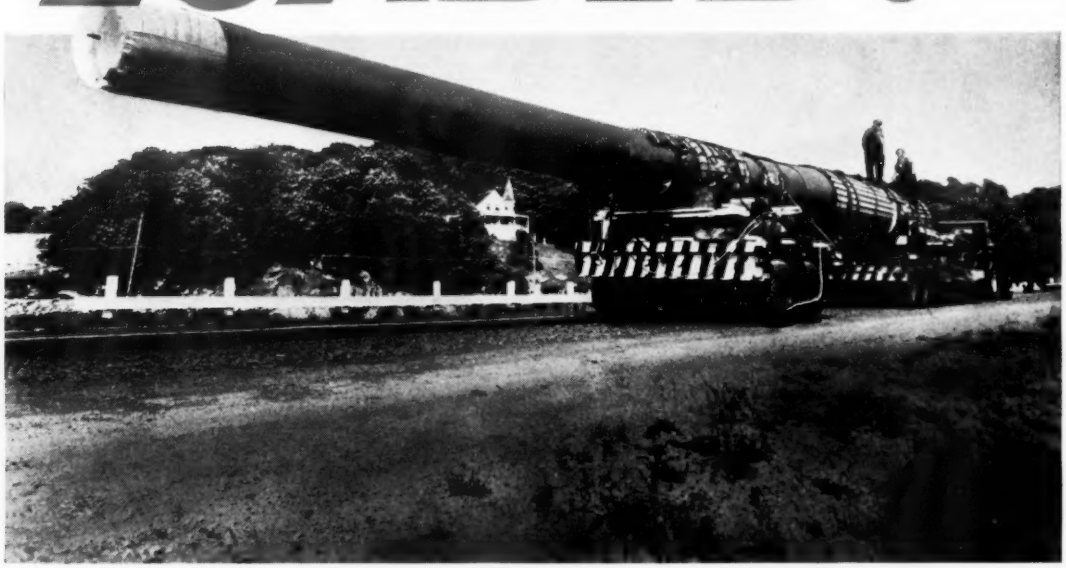

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by
The Texas Company, 135 East 42nd Street, New York 17, N. Y.
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Vol. XXX July, 1944 No. 7

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Oil "Breakdown"?

THE word "Breakdown" as applied to lubrication is probably one of the most commonly used and misused words in the field of lubricating oil parlance. Lubricating oils do not "breakdown" in the normally expected service for which they are intended. "Breakdown" implies decomposition, disintegration and molecular disruption. These are phenomena which occur only when the oil is subjected to conditions of temperature and pressure completely outside the field of "lubrication." Long before the lubricant will "breakdown" in the true scientific sense, the machine or part being lubricated would have ceased to function.

Unfortunately the word "breakdown" as a synonym for "lubrication failure" has been so widely accepted that this challenge to its usage may have to become a crusade. The habit even prevails among some of the well-informed in the oil industry itself.

To correct this misuse of the word "breakdown," education and discussion of those factors which contribute to lubrication failures are needed. For example there are lubrication failures due to fuel dilution; failures due to increase in temperature; failures due to overload; failures due to speed-up. None involve "breakdown" of the lubricants involved, though some condition of operation may have contributed to their deterioration. This brings to mind what Webster has to say. According to the Collegiate Dictionary "breakdown" is,

"1. A breaking that causes collapse, such as of machinery or health. 2. Chemical decomposition. 3. A noisy, rapid, shuffling dance."

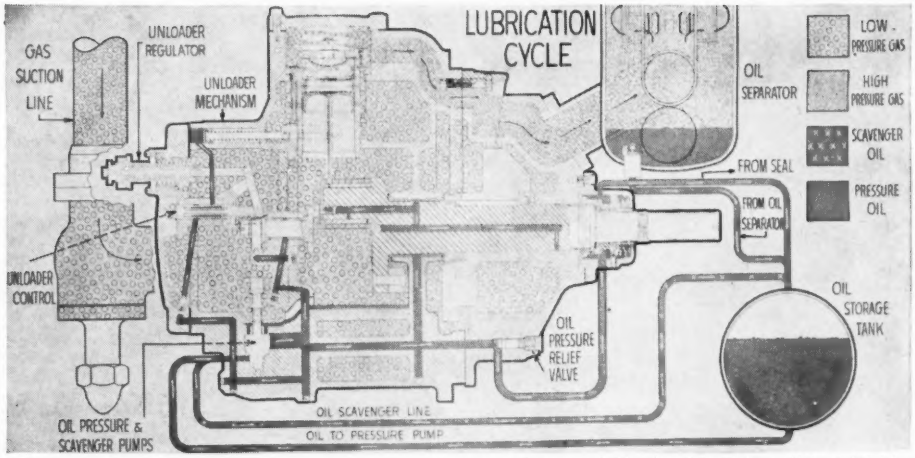
"Deteriorate" in turn is defined as, "to make or grow worse; to impair; degenerate. Deterioration implies impairment of quality, character or value."

The word "deterioration" aptly describes the state of a lubricating oil which has been impaired in lubricating value.

THE past few years have seen some remarkable developments in engineering design. Speeds have been doubled, even tripled as in metal grinding. Temperatures down to —100° F. are now encountered as in stratosphere flying. Pressures and temperatures of unpredicted intensity prevail in many modern mechanisms.

All this required like progress in petroleum research to develop lubricants which would function under these conditions, to avoid failure. This has been accomplished. Lubrication enables machinery to operate more dependably than ever, even in the face of high and low temperatures and extreme pressures.

Meanwhile, the oxidation process — one of the most active contributors to "lubrication failure" — has remained unchanged. Its action, however, can be effectively delayed or reduced in proportion to the type of lubricating oil or grease selected for the service involved, and the extent of exposure to high temperature and oxygen in this service.



Courtesy of Chrysler Corporation, Airtemp Division

Fig. 1—Lubrication cycle of Chrysler's Airtemp radial compressor showing direction of flow of oil and essential equipment, all of which protects against lubrication failure.

CHEMICAL DECOMPOSITION

Of the three definitions of "breakdown" only the second — "Chemical decomposition" — can apply to lubricating oils, and even then not in the commonly used sense.

Chemical decomposition is defined as the dissolution of a chemical compound into two or more different compounds or elements. For example,

$2\ H_2O$ (Water) decomposes to $2\ H_2$ (Hydrogen) $+$ O_2 (Oxygen)

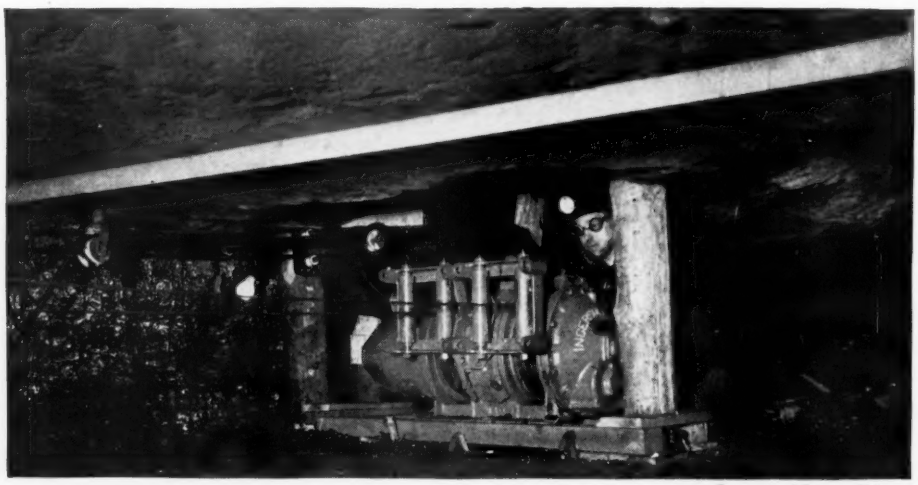
$C_2H_4(COOH)_2$ (Succinic Acid) decomposes to C_2H_4 (Ethylene) $+ 2\ CO_2$ (Carbon Dioxide) $+ H_2$

$C_6H_{12}O_6$ (Fruit Sugar) decomposes to $2\ C_2H_5OH + 2\ CO_2$ (Ethyl Alcohol)

C_2H_5OH (Ethyl Alcohol) decomposes to $C_2H_4 + H_2O$ (Ethylene)

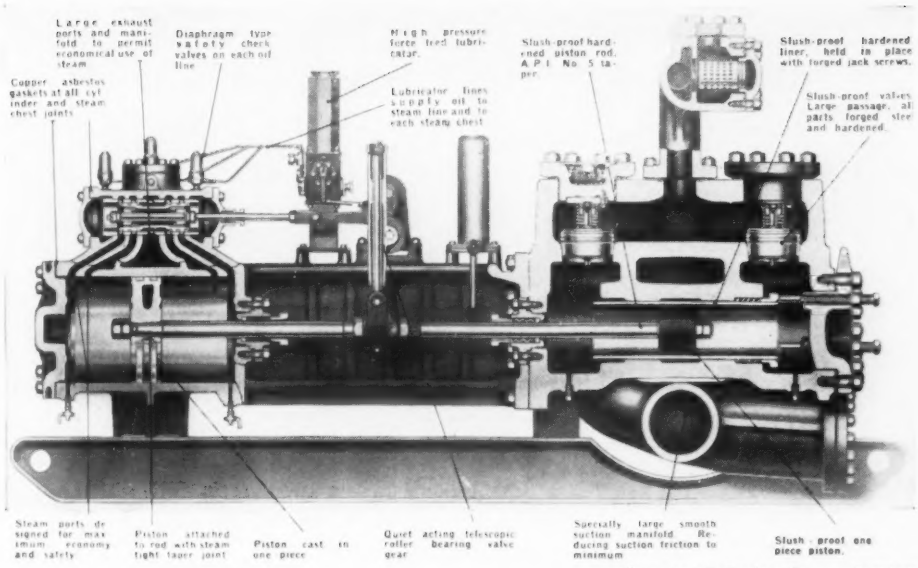
HOOCH (Formic Acid) decomposes to $CO + H_2O$ (Carbon Monoxide)

It is apparent from the accompanying table that in cases involving chemical decomposition a material has been changed into other materials of simpler or less complex structure, and always into materials which separately are smaller in the molecular sense than the original parent compound. As previously



Courtesy of Ingersoll-Rand

Fig. 2—The electric tugger hoist which Ingersoll Rand builds for coal handling, is also built for effective lubrication.


Large exhaust ports and manifold to permit economical use of steam
Diaphragm type safety check valves on each oil line
High pressure force feed lubricator.
Slush-proof hardened piston rod. A.P.I. No. 5 taper.
Slush-proof hardened liner, held in place with forged jack screws.
Copper asbestos gaskets at all cylinder and steam chest joints
Lubricator lines supply oil to steam line and to each steam chest
Slush-proof valves. Large passage, all parts forged steel and hardened.
Steam ports designed for maximum economy and safety
Piston attached to rod with steam tight taper joint
Piston cast in one piece
Quiet acting telescopic roller bearing valve gear
Specially large smooth suction manifold. Reducing suction friction to minimum
Slush-proof one piece piston.

Courtesy of Gardner-Denver Company

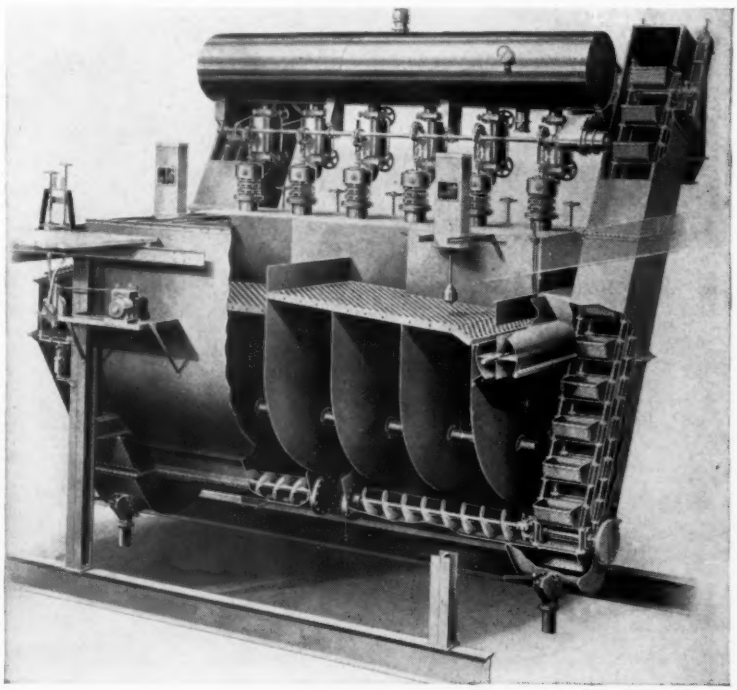
Fig. 3—Details of a Gardner-Denver Duplex steam slush pump for oil field service.

stated lubricants can be chemically decomposed, but not at the temperatures and pressures which exist ordinarily in lubricated mechanisms.

The petroleum industry learned many years ago how to decompose the various hydrocarbons which make up the crude oil with which the industry works. This process was called cracking; it produced the fuel which led to the expansion of the automotive industry, since by this process heavy, non-volatile hydrocarbons in the gas oil, lubricating oil, wax, and heavier ranges can be cracked or chemically decomposed to form substantial quantities of gasoline. As a matter of fact more gasoline is now made by cracking than naturally occurs in the crude oil. Careful scheduling of cracking operations in the refineries allows a balanced production of all the petroleum products necessary to our normal economy without attendant waste.

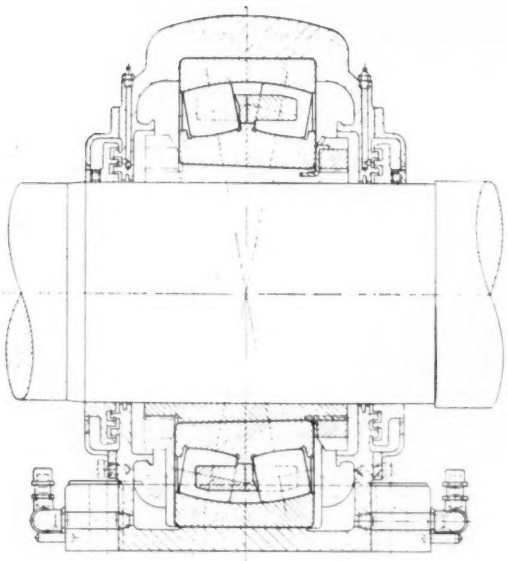
This controlled chemical decomposition is made to take place in the liquid phase at elevated temperatures and under very high pressures. These conditions do not occur in lubrication, consequently lubricants are not subjected to decomposition conditions in normal service. It is therefore absolutely incorrect to state that an oil has *broken down* when used as a lubricant.

However, lubricants can deteriorate in service.



Courtesy of Link-Belt Company

Fig. 4—The Link-Belt Simon-Carves coal washer. Note screen and conveyor design which provides protection for the lubricated parts.



Courtesy of S.K.F. Industries, Inc.

Fig. 5—Showing how S.K.F. designs the bearing mounting for a pulp grinder shaft, so as to prevent lubrication failure.

Deterioration is generally accepted as meaning the occurrence of a change in a product or mechanism which makes it less desirable, unusable for the purpose intended, or of reduced value or usefulness. Lubricants deteriorate for a number of reasons, some of which are the fault of the lubricant or the use to which it was applied. More often this deterioration is due to contamination or the malfunctioning of the lubricated mechanism or an associated member due to improper maintenance or faulty operations. It will be of interest to cite some cases.

LUBRICANT DETERIORATION (INTERNAL CAUSE)

If a lubricant is exposed to high temperature and oxygen it will eventually *oxidize*. The length of time before this occurs and the extent to which it occurs depends on the temperature, the extent of exposure to oxygen and catalytic metals and the ability of the lubricant to withstand oxidation.

Oxidation is usually a cumulative process in that continued exposure to oxidizing conditions continues the oxidation reaction. It is usually an accelerating process since the oxidized materials appear to promote further oxidation beyond the normally expected rate. Not only do more and more lubricant molecules start the oxidation process as time goes on, but molecules which have started to oxidize continue oxidizing to make more complex compounds. As an illustration of this, methane, the simplest hydrocarbon molecule—formula CH_4, progressively oxidizes as follows:

Methane CH_4	oxidizes to methanol CH_3OH
Methanol	oxidizes to formaldehyde CH_2O + H_2O
Formaldehyde	oxidizes to formic acid HCOOH
Formic Acid	converts to $CO + H_2O$
CO	oxidizes to CO_2

Similarly as the various more complex molecular types in a lubricant go through the oxidation process they successively form

Hydrocarbon	⟶	Aldehyde or Acid
Aldehyde or Acid	⟶	Resin
Resin	⟶	Varnish
Varnish	⟶	Lacquer
Lacquer	⟶	Carbonaceous material and coke

Regardless of the care taken in refining a lubricating oil or the extent to which it is fortified with additives, it can be oxidized, given enough time, temperature and exposure to oxygen. The extent to which an oil will oxidize depends as indicated upon five conditions:

1. The ability of the oil to resist oxidation.
2. The extent to which oxygen (air) is in contact with the oil.
3. The temperature at which the contact occurs.
4. The length of time of exposure to oxygen and temperature.
5. The presence of any material which can act as a catalyst.

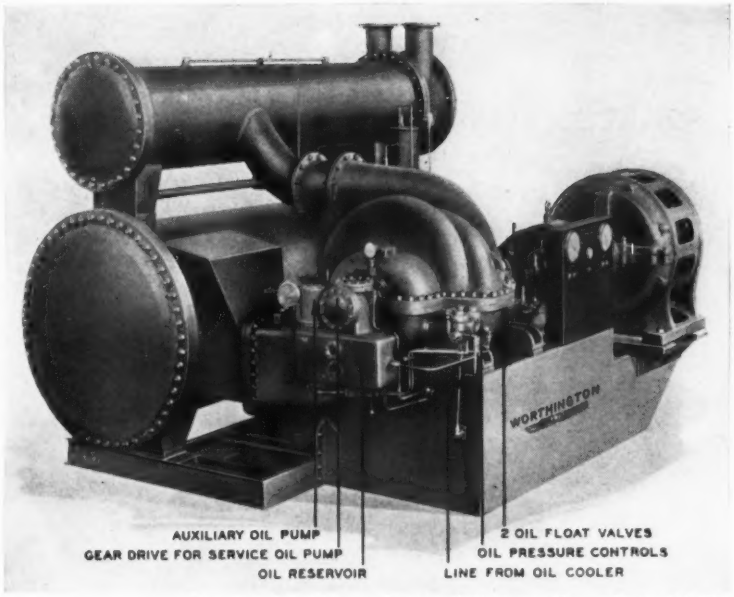
Normally hydrocarbons oxidize rather readily; the tendency to oxidize decreasing as the molecular structure increases in size.

There are two ways in which oxidation can take place.

1. When hydrocarbons burn to H_2O (Water), CO (Carbon Monoxide), and CO_2 (Carbon Dioxide) the hydrocarbon actually splits up or decomposes as previously described.

2. When temperatures are not high enough to cause burning the oxygen generally adds itself directly to the original molecule, and as this step proceeds the molecule becomes more oxidized according to the schemes outlined previously.

In the case of the large lubricant molecules the oxidized materials may link together or combine to form still larger molecules which result in the sludges of various kinds found in systems where the lubricant is not removed before this severe deterioration has occurred.



Courtesy of Worthington Pump and Machinery Corp., Carbondale Div.

Fig. 6—The Worthington-Carbondale centrifugal compresser showing external details of the lubricating system.

AIR NECESSARY FOR OXIDATION

If air can be excluded or kept away from lubricating oil the latter cannot oxidize or deteriorate of its own accord. It is impossible to accomplish this completely in most designs and mechanisms; in fact, it may even be inadvisable in a few cases such as an internal combustion engine which is running at low jacket temperatures and low output as in "stop and go" driving. Under such conditions water vapor of combustion may be condensing on cylinder walls and working into the crankcase oil. This condition can form an emulsion-sludge which will freeze on oil pump suction screens during sub-freezing weather and starve the engine of lubricating oil. In this case it is necessary to adequately ventilate the crankcase to sweep out as much water vapor as possible.

EFFECT OF TEMPERATURE ON OXIDATION

Temperature exposure of lubricating oil can often be easily controlled. The benefits are self-evident.

It is a chemical axiom that most reaction rates double with every 18°F. increase in temperature, and oil oxidation is not an exception. At lower temperatures this is not serious, as temperatures are increased, however, the effect becomes progressively more marked.

Attention to this design or installation detail is often the distinguishing feature between two similar engines or mechanisms which are otherwise similar except that one is pronounced "hard on lube oil."

LUBRICANT DETERIORATION (Externally Caused)

1. Dilution

Lubricating oils are made in a wide range of viscosities in order to afford protective

Courtesy of American Hoist and Derrick Company

Fig. 7—In materials handling, lubrication failures may occur if all operating parts are not well protected. A. H. & D. Co. provide for protected lubrication on all such equipment they build.

Courtesy of Koehring Company

Fig. 8—In earth moving and contracting operations, machinery also must be designed for lubrication in the presence of abrasive foreign matter. Good sealing prevents entry and assures against lubrication failures.

films at the temperatures and pressures existing at the lubricated surfaces. It is quite possible for internal combustion engines to pass unburned fuel, or for reciprocating compressors to pass the compressed gas into the lubricating oil, thus diluting the latter or reducing its viscosity. If the viscosity is thus reduced below the safe lower limit for the lubricated system, trouble results; the failure often being erroneously charged to lubrication breakdown, although the oil was not deficient in itself.

2. Contamination

Internal combustion engine fuels are usually hydrocarbons, meaning they are made up of materials composed of hydrogen and carbon. In burning, the hydrogen combines with oxygen in the air to form water, and the carbon combines with oxygen to form carbon monoxide or carbon dioxide. This means that the fuel molecules are actually chemically decomposed under combustion conditions so that hydrogen and carbon combine with oxygen before the burning is completed. Improper combustion can result in the presence of unburned carbon particles, some of which work their way past the pistons into the lubricating oil. Also any lubricating oil which finds its way into the combustion chamber is almost certain to burn incompletely, resulting in combustion chamber carbon deposits and some carbon particles working down into the crankcase.

Fuel additives such as anti-knock compounds are often difficult to burn completely, and will, as a result form unburned residues which also can work down into the crankcase.

From the time a cold engine first starts until the temperature on the cylinder walls has risen above the dew point, (which may take several minutes), the water vapor formed by burning the hydrogen component of the fuel will condense on the cylinder walls and in part work down into the crankcase. Leaky cylinder head gaskets or cylinder liner seals also will permit water and anti-freeze materials to enter the crankcase.

Operation of any equipment under conditions conducive to abnormal wear of lubricated parts permits quantities of powdered metal to enter the lubricating system.

Dust is one of most common external contaminants of lubricants and means for straining all air entering a lubricating system will be worth while wherever practicable.

In reciprocating machinery compressing gases or liquids (air or refrigeration compressors or pumps) it is impossible usually to keep the medium being pumped from contaminating the lubricating oil or vice versa. In the majority of cases means are provided for handling this type of contamination if it imposes a detrimental effect.

In refrigeration compressors utilizing halogenated refrigerants such as the "Freons" it is common practice to allow for the diluting effect of these materials on the lubricating oil when selecting the viscosity of the latter.

In some designs it may be possible for greases, through overheating or over-application, to reach portions of an allied system designed for fluid lubrication. This will eventually lead to trouble.

Use of the wrong type of lubricant also can be regarded as a cause of external contamination.

There are, surprisingly enough, many records of cases where make-up oil or grease of an incorrect type was added to the system. The results ranged all the way from no damage to complete failure of the lubricated mechanism.

MANAGEMENT'S RESPONSIBILITY

The cost of upkeep in the maintenance of bear-

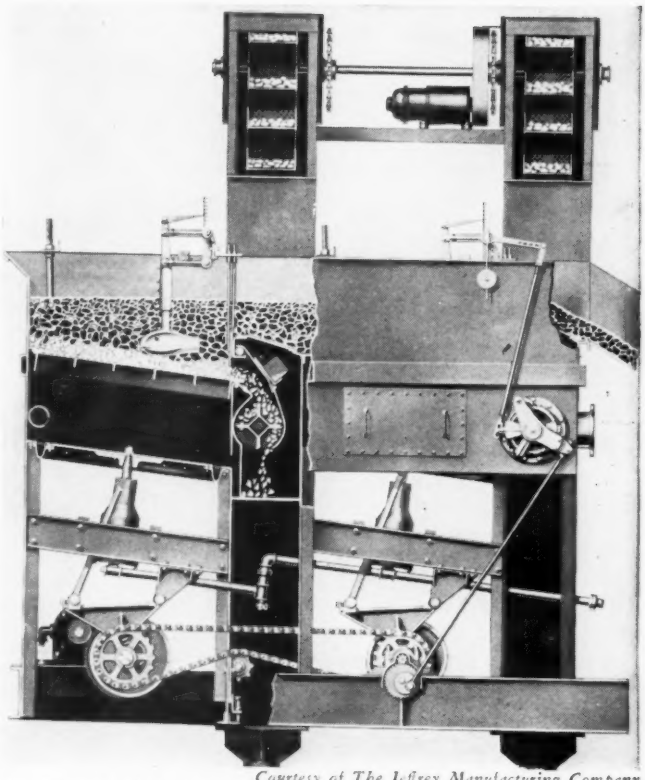
ings, pistons, gears, chains, etc., in proper condition to function efficiently may vary widely. Effective lubrication is insurance in this regard, it is the secret of minimum friction, reductions in wear, and dependable operation of machinery as a whole.

The cost of lubrication rather than the cost of lubricants should be given primary consideration. Those who have studied these details in power and industrial plant operation fully realize that there is more to the cost of lubrication than just the initial cost of the necessary lubricants, their means of application and the labor required.

Unfortunately, the unit cost idea, as applied to initial expense for lubricants, does not always lead to ultimately the lowest cost for lubrication. Many variables may be present which must be considered. These will have to do with operating conditions in the plant, means and methods by which lubricants are handled and applied, and the relative cost of the amount of lubricants needed with respect to the work required.

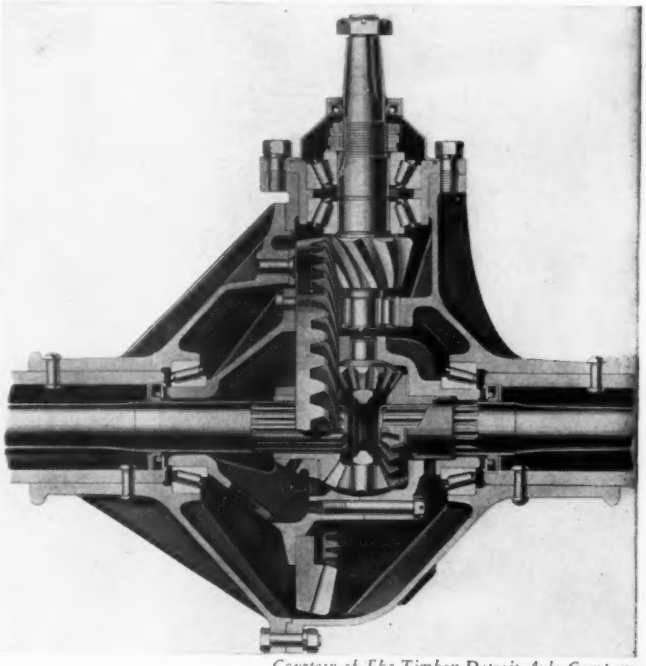
Lubrication is furthermore a most decided factor in the maintenance of production schedules. Production will depend naturally upon keeping machinery running. There is no more prevalent mechanical cause for cessation of operation than imperfect or insufficient lubrication. As a result, in view of the fact that the management is responsible for production, naturally their interest should be centered upon this most important adjunct to operation. There was a time when lubrication simply required the application of lubricants; also the greater the volume used the more effectively did we believe the plant was running. Today, however, this idea has been disproved. Conservation of lubricants, and decrease in costs of maintenance and labor must be considered.

Lubrication is directly related to the cost of maintenance and repair, for if lubrication is not carried out by products suited to the operating conditions, maintenance cannot be dependably controlled. In other words, regardless of how efficient a lubrication system may be, if the lubricant is not suited



Courtesy of The Jeffrey Manufacturing Company

Fig. 9—Details of the Jeffrey diaphragm jig for coal washing, showing working mechanisms.



Courtesy of The Timken-Detroit Axle Company

Fig. 10—Gear arrangement in a typical Timken bevel drive rear axle with split type housing.

for the purpose, or if it has been stored and handled in a careless manner and allowed to become contaminated with dirt or other foreign matter, there will always be danger of wear, overheating of bearings or faulty circulation, which will lead ultimately to failure of some part of the machine. This is when repair bills become abnormal and disruption of the production schedule occurs.

EXECUTIVE COOPERATION

The advancements which have been made in lubrication over recent years render it highly advisable for the industrial and power plant executive to keep pace with this progress, just as the lubricating engineer has kept pace with industrial and machine development. This will lead to maximum production with minimum operating costs. Furthermore, the executive must realize that it is scientific research, not advertising propaganda, which dictates that there is usually a grade of lubricant best suited for each and every type of operation, as indicated by its physical characteristics and chemical stability.

This ultimate maximum of efficiency in the usage of lubricants, however, is only attainable through continuous cooperation between plant executives and engineers, and the lubricating experts representing the oil industry. For this reason it is advisable, where the volume of lubricants concerned will warrant, to employ a lubricating engineer whose duties should be the supervision of plant lubrication. He should preferably be a technical man, familiar with machine details and lubricating equipment, conversant with the types of lubricants available on the market, and able to plan and carry out practical experimental work to prove the adaptability of such products with respect to operating conditions.

In cooperation, the petroleum industry is devoting intensive research relative to the development of lubricating oils and greases which will be adapted in every characteristic for the function they are intended to perform. Naturally a wide range of conditions must be taken into consideration in this work due to the fact that many plants will operate similar machines quite differently, and grades of lubricants that would be suitable in one may be unsuitable in another, due to such elements as excessive speeds, heat, water, acids or other chemicals. It is a broad subject, but one wherein cooperation will solve many of the minor problems, and so govern matters that the seriousness of the larger problems will be reduced to a marked degree, with decidedly favorable reaction upon the cost of lubrication irrespective of the initial cost of the lubricants employed.

Many of these problems are largely dependent upon the care with which the lubricants are originally selected and the intelligence of the operators who have to do with their storage, handling and application. The amount of care which must be given to selection of lubricants will, of course, depend in turn upon the reliability of their source. If bought from a refiner of recognized integrity, furnishing engineering service and technical advice to its customers, the possibility of its products becoming involved in difficulties will be far less than where lubricants are bought by the user according to his own ideas, and without regard to engineering principles or lubricant characteristics. Hence the value of lubricating engineering service;—the purpose of which is to increase machine efficiency and production to a maximum by the elimination of lubrication problems wherever possible, and to develop the most economical cost of lubrication. Obviously, this is intimately related to cost of upkeep and maintenance.

CONCLUSION

Regardless of the extremes to which the petroleum refiner may go in careful selection of stocks, refining methods, blending, and fortification of lubricating oils and greases with additives, it is possible to deteriorate these carefully prepared products. Technological advancements have produced lubricants capable of performing services unheard of a few years ago. However, contamination in service and deterioration because of oxidation still constitute formidable barriers to prolonged usage.

Careful selection of the proper lubricant and rigorous attention to control of operating temperatures and oxygen exposure will insure good service. Scrupulous care to avoid or minimize contamination will prolong the life of the lubricant and the machine.

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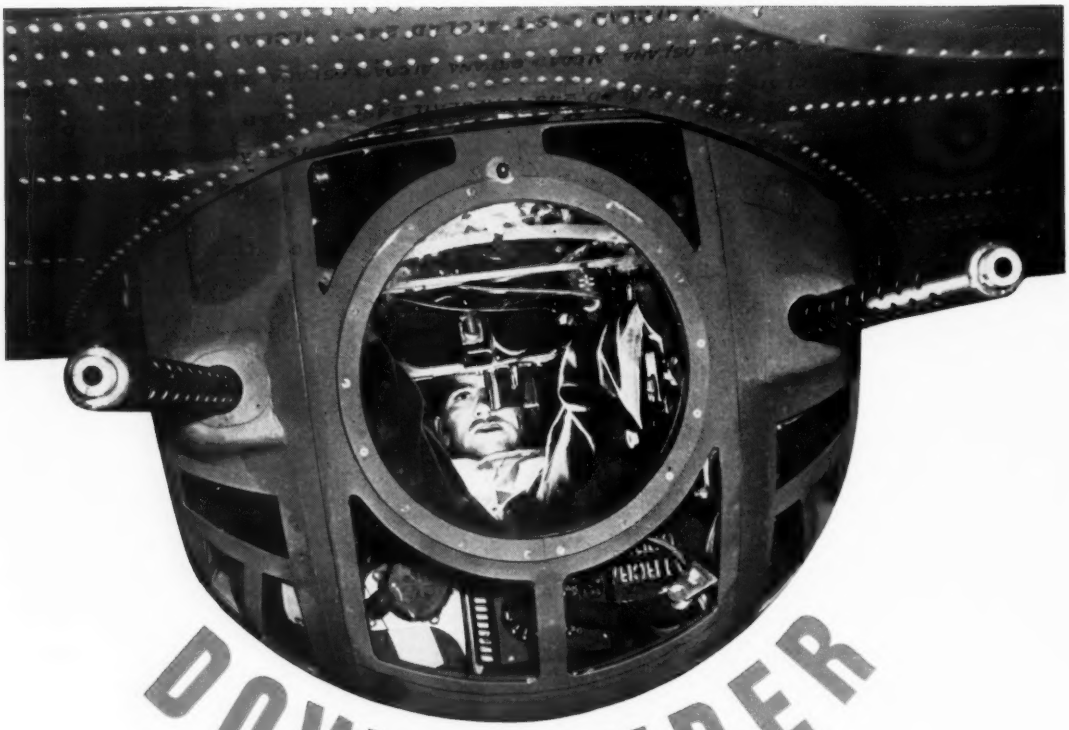

DOWN UNDER

BALL turrets of high flying bombers are right out in the open, exposed to numbing cold of 80 below and lower. In this intense cold the operating mechanism may freeze up, become as rigid as though one piece.

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